Technical Assignment I:

2011 AE Senior Thesis
Office Building
Northeast, United States

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Patrick Laninger

Construction Management
Dr. Robert Leicht

EXECUTIVE SUMMARY

While this thesis project will focus on Building One, the entire structure features three large tiered buildings. These structures sit on a large sloping hillside, and are connected to one another by hallways and outdoor walkways. Building One also attaches to Building Two via a steel pedestrian bridge. The entire office building as a whole is 1.2 million square feet in size, 390,000 of which is contained within Building One. The building consists primarily of open office space, later to be filled with moveable partitions, but also features multiple conference rooms, kitchenettes and a 45,000 square foot childcare center.

In addition to its confidential purpose, name and owner, the office building featured in the following technical analysis has numerous unique aspects, including a X gallon storm water retention pond, X square feet of green roof space, and blast resistant curtain walls. The design also features a mechanical, electrical and plumbing system that is entirely independent of buildings two and three, which are connected to building one by two underground passageways and an elevated pedestrian bridge. Although the buildings are not able to be quarantined from one another, the nearby central utility plant provides localized utilities to each of the three tiered structures. This greatly improves the mechanical efficiency of the building and when coupled with the localized variable air volume boxes, extensive insulation, low conductivity glass and green roof spaces, helps the project achieve its LEED gold rating.

The coordination of the aforementioned unique aspects is made possible by the design-build delivery method implemented on the project. The intense MEP, façade, and landscaping coordination techniques that are being utilized on this project allows the building to effectively combine numerous green aspects in a harmonious manner that capitalizes on the benefits of the systems being used.

Throughout excavation and prior to erecting the cast in place foundation and pond walls, Building One required substantial sheeting and shoring systems that held back the hillside for the partially underground Lower Level 9, as well as the western wall of the storm water retaining pond. Structurally, the building sits atop of steel piles and concrete pile caps, with a system of concrete grade beams for additional load bearing capabilities. The foundation walls, mat slabs and elevated slabs are all cast in place, due to the regional preference of CIP over precast applications, as well as the ability to utilize tower cranes that are far more suitable for the hillside site as opposed to crawler and truck cranes.

Mechanically, the office campus features a central utility plant (not included in this thesis) that houses three large boilers that feed the buildings with steam that is utilized in a localized VAV system that is fed by eight air handling units located throughout the building. Medium and low-voltage switchgear rooms distribute power to the building. The medium voltage switchgear has a redundant emergency switch gear system located in an adjacent room.

The following data supports these major findings and explains the building's features, systems, construction process and design history in further depth.

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SUMMARY PROJECT SCHEDULE

*** See Appendix A for Summary Project Schedule**

FOUNDATIONS PHASE

Due to the integration of the structure into a large hillside, the foundation system on this project is extremely complex. After excavation, it was discovered that the soil bearing capacities reported in the initial geotechnical analysis were very generous, and that if the building was built per the contract documents, major differential settling would occur over time. Consequently, Clark Construction proposed a $53M change order that incorporated global stability caissons into the design, some of which were in excess of 8' in diameter and 100' deep. Fortunately, Building One is the smallest of the three buildings and did not require the addition of caissons beneath its mat foundations.

The foundations beneath Building One are comprised of rolled W-shaped column piers and concrete pile caps that support a system of grade beams that range in size from 716mm x 915mm to 1600mm x 915mm. In some places, a 1220mm thick mat slab sits atop the grade beam system to provide adequate load distribution for the floors above, while a 127mm slab on grade is located in areas with lesser building loads.

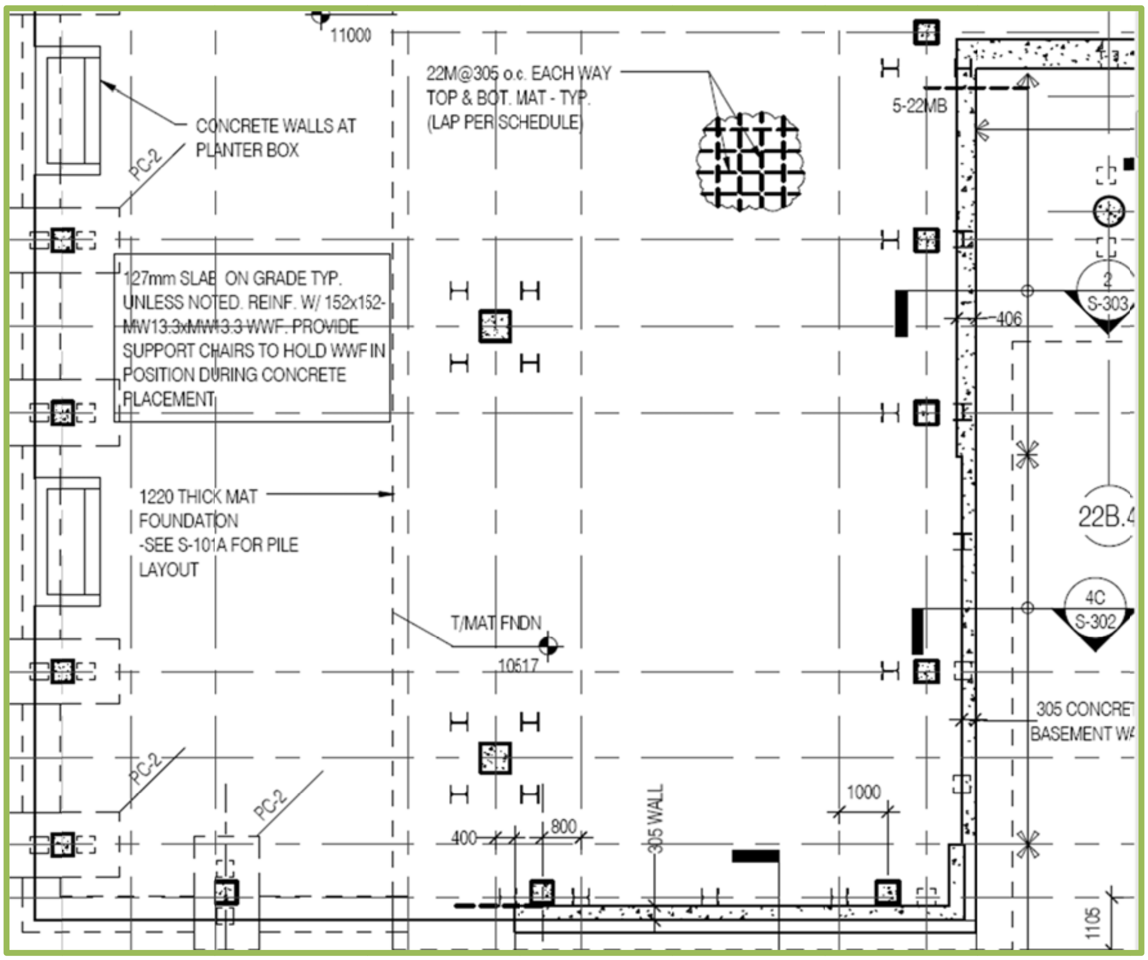


Figure #1: Lower Level 9 – South Finger Foundations

STRUCTURAL PHASE

The elevated concrete deck pours in Building One progress from North to South (red to blue to green in the image). Each level is completed prior to jumping to the floor above due to the structural stability requirements of the design. The only area that does not follow this sequence (highlighted in yellow) serves as the main connector between Building One and Building Two and is to be completed once the interior courtyard (highlighted in dark green) has reached a substantial level of completion. These pours are omitted from the standard sequence in order to maintain courtyard accessibility.

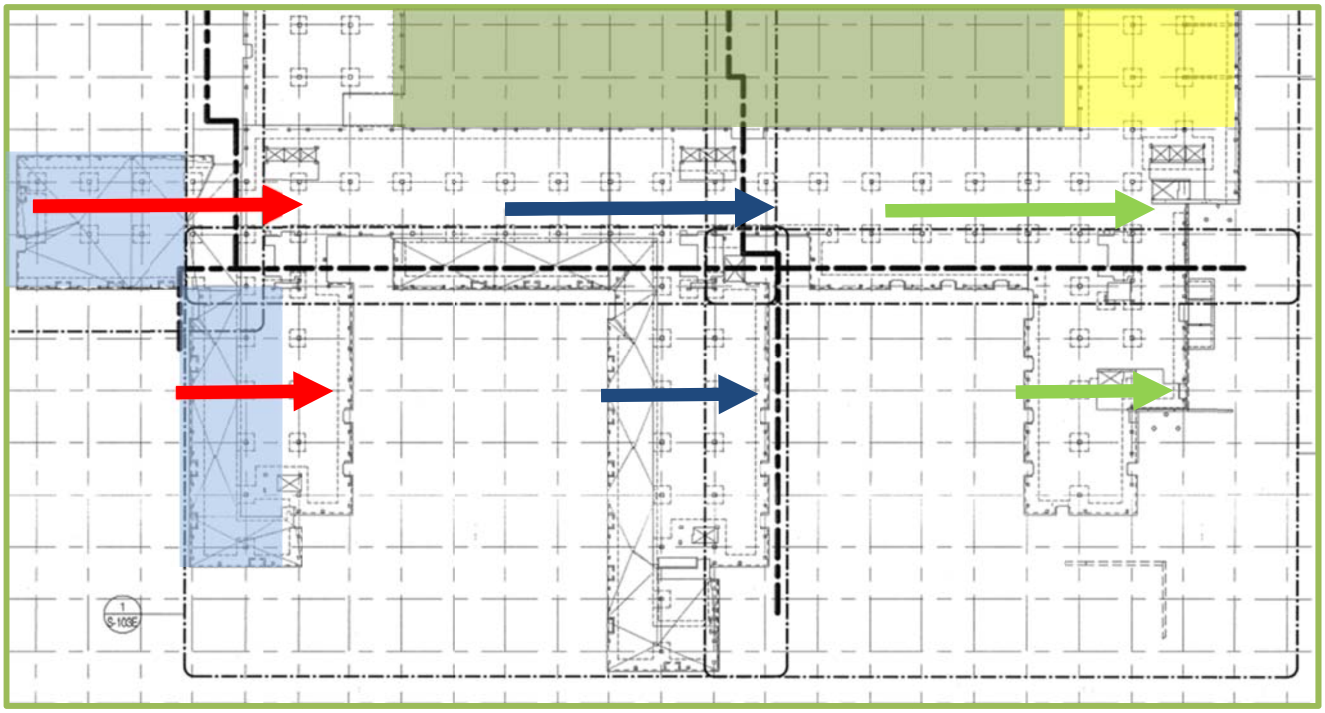


Figure #2: Building One Pour Schedules

FINISHING SEQUENCES

The project is phased such that the buildings are watertight in ascending order, from one to three. Therefore, Building One's superstructure, façade and waterproofing are currently complete, and MEP systems and partition walls are in place on Lower Level 9. The high-end interior finishes will progress vertically, starting on Lower Level 9 and finishing on Lower Level 6. Due to the complexity of the curvilinear walls in the childcare area (highlighted in light blue above) the interiors field management decided that interior partitions and finishes should begin in this area so that initial quality control measures could be stringently enforced, effectively setting the interior trades up for future success on the rest of the building. The interiors division strongly believes in constant initial oversight that establishes expectations early on in this phase of construction so that future issues can be avoided and productivity will steadily increase as the phase moves forward. Interior finishes will progress through each floor in the same sequence as the concrete pours followed.

BUILDING SYSTEMS SUMMARY

Yes	No	Work Scope	If yes, address these questions / issues
	X	Demolition Required?	Types of materials, lead paint, or asbestos?
	X	Structural Steel Frame	Type of bracing, composite slab?, crane size / type / location(s)
X		Cast in Place Concrete	Horiz. And Vert. Formwork types, concrete placement methods
	X	Precast Concrete	Casting location, connection methods, crane size / type / location (s)
X		Mechanical System	Mech. room locations, system type, types of distribution systems, types of fire suppression
X		Electrical System	Size/ capacity, redundancy
X		Masonry	Load bearing or veneer, connection details, scaffolding
X		Curtain wall	Materials included, construction methods, design responsibility
X		Support of Excavation	Type of excavation support system, dewatering system, permanent vs. temporary

CAST IN PLACE CONCRETE

All of the foundation walls, mat slabs, and elevated slabs in Building One are cast in place concrete. Clark Concrete, the concrete sub-contractor, specializes in cast-in-place concrete structures and accounts for approximately one third of the 350 workers that are on the site each day.

The concrete structure is comprised of X ft. x X ft. typical bays, with XxX columns and X" thick floor slabs. In order to reduce the financial burden of the original X" thick floor slab design, Clark Construction, with the help of Cagley & Associates, proposed a value engineering change that lessened the slab thicknesses to X", while incorporating drop panels X" in thickness around the columns that maintain the building's structural integrity and blast rating.

MECHANICAL SYSTEM

Building One is serviced by eight McQuay Vision VAV air handling units located in three mechanical rooms. Three air handling units are located in the north finger on lower level 8, two are located on lower level 8 in the middle finger, and the remaining three are located in the mechanical penthouse (lower level 6 south finger). These air handling units feature water coils that are fed by chilled water and hot water pipelines from the Central Utility Plant. In order to achieve LEED points, the McQuay Vision air handling units include three energy recovery devices; heat wheels, fixed plate heat exchangers, and runaround coil loops. Conditioned air is supplied to localized VAV's through medium and low pressure ductwork.

ELECTRICAL SYSTEM

Eleven transformers, ranging in size from 150 KVA to 15 KVA, provide 480/208 power to the building. This power is distributed to the various electrical closets by a medium-voltage switchgear room in the southern end of lower level 9, and a low-voltage switchgear room located one floor above. The medium-voltage switchgear is backed up by an emergency switch gear located in an adjacent room.

MASONRY

10" CMU knee walls, combined with concrete edge beams, create the backing system for the brick masonry façade. The bricks utilized on this project were carefully chosen to match the historical buildings present on the owner's campus. While typical R13 solid foam insulation, air spaces and brick ties are utilized on the project, there is nothing usual about the masonry wall construction. In order to achieve the proper blast ratings, each CMU cell is fully grouted and reinforced with steel dowels. These dowels are HILTI bolted to the concrete slab below, and capped with a locking nut that creates a bond with the grout, providing a rigid frame that resists horizontal movement.

CURTAIN WALL

Blast-rated windows and curtain wall systems are located between the knee walls and concrete edge beams above. These windows are attached to the under-slab and CMU wall by steel embeds. The edge beam connections feature steel spring shock absorbers that allow the curtain wall to move in the event of a blast.

In other areas, the entire façade is comprised of curtain walls. The system is attached to embeds in the concrete slab by steel bolts. The window tops are affixed to the aforementioned blast absorbent brackets that are bolted to the under-slab beams. The windows themselves feature dual pane, heat treated glass, are double-sealed by polyisobutylene and silicone, and are broken up by aluminum mullions. In office areas, the exterior glazing is simply tinted. In mechanical spaces, where there are not air intake louvers, the glass is frosted and opaque to hide the equipment within but maintain the architectural aesthetics of the building. Solar shades are staggered across the entire curtain wall. Some shades are three stories in height, while others only extend one floor in height.

SUPPORT OF EXCAVATION

This project, due to its sloping site conditions, required a substantial amount of excavation support. Steel piles were driven into the ground in areas of deep excavation, including the uphill side of each of the building's footprints. Lagging boards are installed after every 5' of excavation, ensuring a stable earth retention system. The SOE required for the construction of building one included 12' high piles and lagging along the eastern side of the building, as well as a 25' tall system east of the child care wing that is responsible for holding back all of the earth uphill of that location.

PROJECT COST EVALUATION

The following costs are taken from Clark Construction bid documents and are adjusted to provide simple cost comparisons and to protect project details that cannot be released.

PROJECT FINANCIAL DETAILS

Total Square Footage: 390,000 SF
Total Building Perimeter: 2,778 LF

Construction Costs
Total: Approximately $92,000,000
Per SF: $235.90

Total Project Costs
Total: Approximately $115,000,000
Per SF: $294.87

Major Building Systems Costs

MAJOR BUILDING SYSTEMS		
SYSTEM	TOTAL COST	PER SF
CIP Concrete	$11,364,000	$29.14
Masonry	$3,149,000	$8.07
Glazing	$8,053,150	$20.65
Mechanical/Plumbing	$13,354,000	$34.24
Electrical	$13,334,000	$34.19
Fire Protection	$1,185,200	$3.04

Table 1: Major Building Systems Costs

RSMEANS BUILDING COST ESTIMATE

***See Appendix C for RSMeans CostWorks 2011 Square Foot Cost Estimates**

The 5-10 Story Office Building with Face Brick and Concrete Block Back-Up with a CIP Concrete structural frame building type was used for the CostWorks square foot calculation.

Construction Costs
Total: $41,232,000
Per SF: $105.72

Total Project Costs
Total: $46,328,500
Per SF: $118.79

COST ESTIMATE COMPARISON

The primary reason for the large discrepancy between the actual and square foot estimated project costs stems from the fact that the RSMeans CostWorks program does not include Equipment, Furnishings, Special Construction or Building Sitework costs. The excavation and millwork contracts alone account for approximately $10M.

Below is a table that combines the RSMeans CostWorks estimates with some known subcontract values. This approach to estimating the construction costs provides a slightly more accurate budget due to the increased costs associated with the details of the glazing, casework, elevators, fire protection, HVAC, electrical and excavation packages on this project.

HYBRID COST ANALYSIS			
SYSTEM	DATA LOCATION	TOTAL COST	PER SF
Substructure	CostWorks	$1,308,500	$3.36
Shell (Minus Glazing)	CostWorks	$11,112,000	$28.49
Glazing	Actual	$8,053,150	$20.65
Interiors	CostWorks	$8,136,500	$20.86
Casework	Actual	$775,000	$1.99
Services (Minus Elevators/MEP)	CostWorks	$8,283,500	$21.24
Elevators	Actual	$2,650,000	$6.79
Fire Protection	Actual	$1,185,000	$3.04
HVAC/Plumbing	Actual	$13,354,000	$34.24
Electrical	Actual	$13,334,000	$34.19
Excavation	Actual	$9,530,000	$24.44
	Total	$77,721,650	$199.29

Table 2: Hybrid Cost Analysis

SITE PLANS

EXISTING CONDITIONS

* **See Appendix C for Existing Site Conditions Plans**

SITE LAYOUT PLANNING

* **See Appendix C for Site Layout Plans**

Excavation Site Plan
During the excavation phase of the project, construction roads (gray) were installed to provide proper access to the building footprint in order to facilitate a rapid and efficient excavation process. These roads were wide enough for two tri-axle dump trucks to pass, allowing for the staging of trucks to keep up with the dirt moving capabilities of the excavation equipment. These trucks then progressed to the spoils pile, which was conveniently located near the areas with the largest amount of excavation and out of the way of future construction traffic on the site. Two ramps were built into the spoils pile to ensure that the tri-axle trucks could access the dumping areas at all times. Excavation began in the large courtyard (green), and progressed across the building footprint, ending with the removal of soil from the pond area. A collection pond was excavated early in the process and a sediment control tank was brought on site to eliminate the release of sediment into the local storm system.

Superstructure Site Plan
Two tower cranes (yellow) were erected prior to the start of the superstructure phase to ensure that materials could be moved throughout the entire Building One footprint at any given time. One main offload area was established so that the site did not become congested with rebar and formwork deliveries while excavation equipment traveled between the spoils pile and the eastern side of the site where excavation of buildings two and three was taking place. The larger of the two tower cranes was responsible for offloading these trucks and distributing their cargo to one of four laydown areas within its reach. The smaller tower crane could then transport these materials to the areas of the building outside of the swing radius of the larger crane. Placement of the building's floors occurred by floor, starting at the north side of the building and working towards the south (areas 1-3 respectively). Once an entire floor of elevated deck was completed, the process would repeat itself for the next level, again progressing from area 1 to area 3. Upon topping out, the larger of the two tower cranes was decommissioned, and moved to the parking garage area of the site to begin the placement operations of the garage. The smaller of the two tower cranes remained in place, to facilitate the erection of the pedestrian bridge, building two, and eventually the construction of the interior courtyard.

Façade Site Plan
The façade of the building was installed in two major phases, beginning with the northern half of the building. Due to uneven ground conditions, both traditional scaffolding (purple) and FRACO lifts (yellow) were utilized in the construction of the façade. In the Child Care area (north portion of Building One), traditional scaffolding was constructed in the areas of undulating soil grades. Additional scaffolding was implemented in areas that were too constrictive for the use of FRACO lifts, such as the entrance coves on the west side of the building. Man lifts (red) were also used for the limited areas of masonry around the courtyard on the western side of Building One. Various laydown areas for masonry and curtain wall were used to offload and store large amounts of materials due to the rapid erection process required to meet the project schedule. Most of the curtain wall and windows (blue) were quickly moved inside the newly erected building to prevent damage on-site. Brick and stone stockpiles (reddish-brown) were strategically located to ensure easy forklift access to these materials during the façade phase of construction.

Phase two of the façade construction, while very similar to phase one, used far less traditional scaffolding due to the level site conditions in these areas. FRACO lifts were erected in sets of three, around the perimeter of the building. These provided a large working platform from which a large number of workers could set the façade brick quickly and efficiently. Again however, a small amount of traditional scaffolding was required to provide access to the setbacks in the building's façade that were not accessible via the FRACO lifts.

CRITIQUE

While intense planning was put into the development of Clark Construction's phased site plans, a few things could have been improved. For instance, during the superstructure phase, a second material offload area could have been established in order to avoid the double-picking of materials that were required at the south end of the building. This would have freed up the larger tower crane from essentially half of its picks, allowing its operator to focus on the distribution of materials for the north end of the building, expediting the placement of formwork and rebar. Consequently, there may have been some interference between the formwork and rebar deliveries and excavation traffic at the south end of the site, but this could have been avoided through careful delivery scheduling, or by stacking all rebar and formwork deliveries early in the day.

Additionally, as previously mentioned, curtain wall and window materials were lifted into the building for safe storage during the façade phase. These materials were hoisted through the use of a telescoping crane, which takes up a substantial about of room. The efficiency of a single telescoping crane is also not ideal, and could have been improved through the use of a material hoist. This hoist could have been placed near the north end of the building, providing ease of delivery and movement of materials. Once lifted to their proper level, materials could have been distributed throughout the building using pallet jacks and propane powered forklifts. The stockpiling of materials would have been expedited, allowing Harmon Glass to install their systems more rapidly and efficiently.

LOCAL CONDITIONS

CONSTRUCTION METHODS

Due to building height restrictions in the neighboring counties, the regionally dominant structural system is cast in place concrete due to its ability to maximize the number of stories within a structure by eliminating the wasted plenum space associated with structural steel applications. Most general contractors and subcontractors are extremely familiar with the cast-in-place approach to building construction, and prefer this method over the application of structural steel framing.

Surprisingly, Clark Construction developed a value engineering alternative that implemented the use of precast T-beams on the parking garage (not included in this thesis). However, it was decided that the varying grades and continuously changing laydown areas were not conducive to the delivery and erection of precast beams, and the precast approach was determined to no longer be a viable option on the rest of the project.

UNIQUE SITE LOGISTICS

Although the site is one of the largest partially developed tracts of land in the region, with extensive fields and wooded areas, extra space on site was very limited. A number of factors, including the historic nature of the campus, adjacent projects with bordering limits of construction and the necessity for clear access roads and ramps, drastically limits the amount of parking on site. Subcontractors are provided with a designated number of parking passes that they distributed to their foremen. Workers are encouraged to car pool to the site with their foremen, or make use of the nearby public transportation lines and walk the length of the site's access road to gain entry to the site. Unfortunately, the workers continue to park in restricted areas, warranting the punishment of certain subcontractors who are forced to bus their employees to the site for the remainder of the project. In addition to on-site issues, workers began to park in large numbers along the public road to the east of the site. While parking along this road, although inconvenient to locals who lose the use of a driving lane during the day, was legal, the workers began to scatter their litter along the sidewalks and in the grass median, prompting city officials to visit the site and demand a weekly cleanup operation.

Additionally, the secure nature of the site, although monumental to the elimination of material and tool theft, proved to be a logistic nightmare at times. Each and every visitor to the site, whether they are a delivery truck driver, a consultant, or a project architect or engineer has to be screened, badged and checked-in at either of the two main gates. The "guest approval" system put in place by the security company is flawed at times, and sometimes prevents the swift access-to-site of numerous mission-critical guests, leaving the construction process at the hands of the security company.

GEOTECHNICAL

As previously mentioned, the soils on site are much more unstable than initially believed. There are no traces of rock on the entire site, which is comprised predominantly of compressed clay material. Global stability issues prompted the design development of concrete caisson systems that provide the necessary bearing capacity for the large building above. Additionally, the site is very reactive to inclement weather. During dry weeks, the clay material hardens to a state that prompts angular shearing during excavation, making trench digging operations extremely difficult. Conversely, during rainy weather, the site becomes very favorable for surface trenching and minor excavation operations, but does not provide much rainwater absorption, leading to the ponding of water both inside and outside of the buildings. Rainwater remediation efforts demanded the undivided attention of a large portion of the general laborers on site, setting them back on their other responsibilities such as fall protection, access ladder and general carpentry erection and repairs. Fortunately, as the building progresses up the hill and under-drainage is put into place, the severity of these storm water issues is substantially lessened, allowing the rest of the work to progress more smoothly. Fortunately, the elevation and sloped nature of the site lends to the absence of any subsurface aquifers or water tables, eliminating any construction issues associated with the necessity to dewater areas of deep excavation, unless it rains, when most low spots, as previously stated, experience extensive ponding.

SMALL BUSINESS REQUIREMENTS

In a partnership with the United States Small Business Administration (SBA), Clark Construction committed to soliciting and awarding approximately $145M in subcontracts to the following small business groups:

SB – Small Business
SDB – Small Disadvantaged Business
WOSB – Women-Owned Small Business
HUBZone – Historically Underutilized Business Zones
VOSB – Veteran-Owned Small Business
SDVOSB – Service Disabled Veteran-Owned Small Business

In addition to subcontracting requirements, Clark is required to make attempts at employing local residents on the project. In order to achieve this goal, Clark joined a registered Apprentice Participation Program that helps local employees develop the skills required to become skilled craftsmen. Currently, there are 50 local residents that have gone through this program employed on site.

CLIENT INFORMATION

DISCLAIMER

Due to the confidential nature of this project, many details regarding the client and their needs are not releasable. Please forgive the lack of in depth client information and understand that it was the wish of the client to maintain anonymity.

CONSTRUCTION MOTIVES

This project is to serve as the tenant's flagship headquarters, and was approached by the owner as a Design-Build RFP for two main reasons. The first, the project required an aggressive, fast tracked schedule (see Figure #3) in order to meet the owner's long term goals for the relocation of multiple properties in an attempt to streamline their operations. Secondly, the owner is very confident that the Design-Build approach will allow them to meet their sustainable goals through the integration of a design team capable of incorporating sustainable aspects in the building's design, and a contractor/subcontractor presence that will provide continual cost analyses of the proposed building features. They strongly believe that together, this designer/contractor team will be able to deliver a high-end, high-value product in a substantially shorter amount of time when compared to a traditional design-bid-build approach.

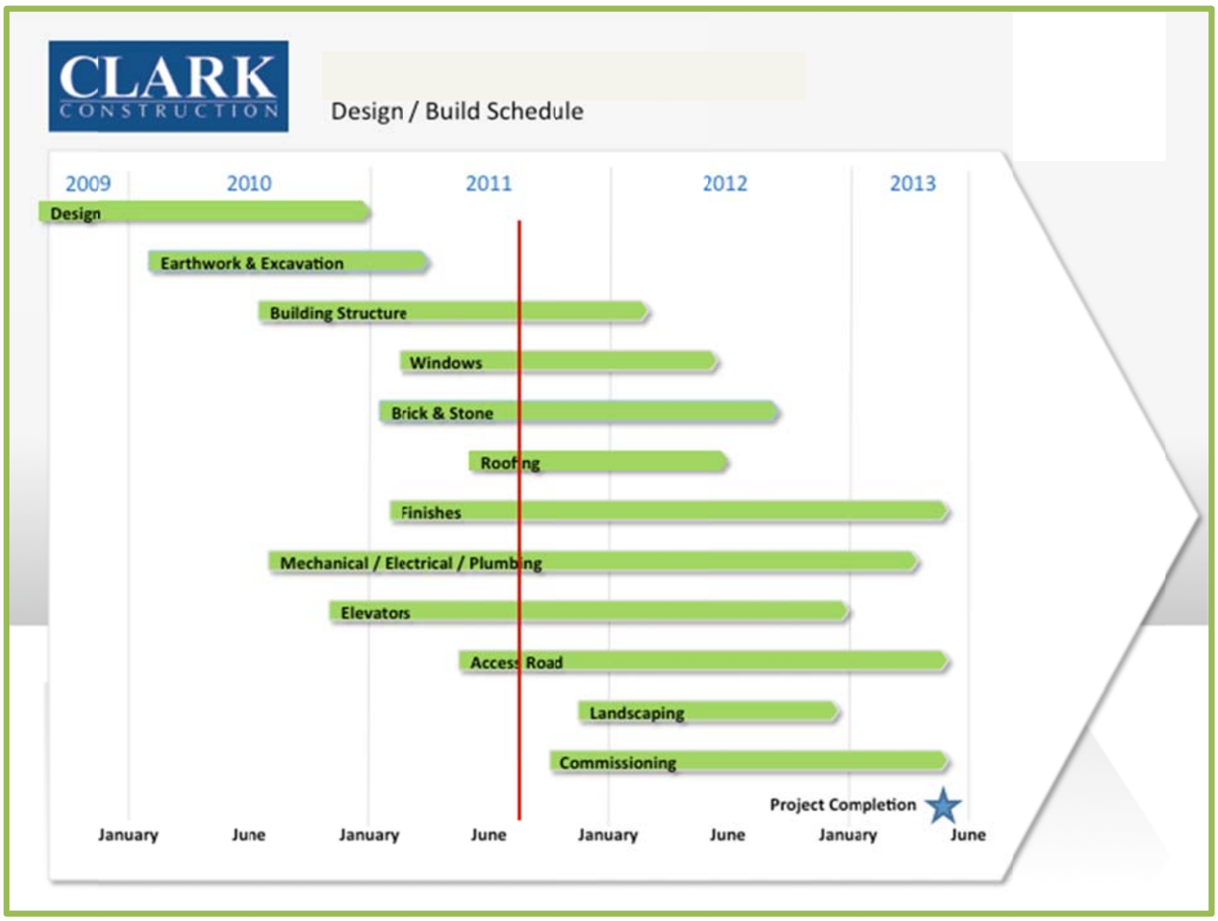


Figure #3: Total Building Schedule Courtesy of Clark Construction

In order to successfully meet the owner's schedule acceleration desires, Clark Construction, with the help of its design subcontractors, HOK, WDG and McKissack and McKissack, approached the bridging document development and design process with the idea of beginning excavation soon after this process began. Luckily, the bridging documents, developed by Perkins & Will, outlined the owner's desired building footprint and basic structure. This allowed the design team to produce site, civil, and foundation drawings early in the design process, expediting the release of the associated contracts which permitted groundbreaking and site development operations to begin early in the design process. This overlap of design and construction is crucial to the time-based success of the project. Additionally, the tiered design of the project allows for the phased construction of the building. Excavation efforts began on the lower part of the site and worked uphill, allowing the foundations and structure of Building One to begin shortly after the site was prepare, while excavation activities progressed up the slope. This ultimately allows for the phased construction of Buildings One, Two and Three respectively, so that the façade, MEP and interior trades can essentially "chase" one another up the tiered structure. This staggering of trades further exploits the advantages of the fast-tracked approach to building construction. While phased-occupancy requirements COULD be met through this fast-tracked approach, the owner has not chosen to implement any such requirements on the design-build team at this time.

Due to the dilapidated state of the their current facilities and the fact that this office building will serve as the their main headquarters for many years to come, the owner committed to spending approximately $550M on the project in order to provide their employees with a state of the art, sustainable facility that surpasses the quality of similar facilities in the area. The owner is determined to provide a facility that will promote productivity, worker satisfaction, and provide a high level of security and safety to its occupants. These goals are met through the utilization of ample day-lighting, extensive interior courtyards, and state of the art security and blast rated systems.

In addition to their sustainable and space utilization goals, the owner also expects a high level of quality from the design-build team. To ensure that these expectations are met, Clark partnered with McKissack and McKissack's quality control division in a quality assurance subcontract separate of the CUP and Garage design contract. The quality control team is responsible for overseeing water tests on all of the MEP systems, operational tests of the vertical transportation systems, and wall close-in inspections. KTLH Engineers and ECS Testing Services were also subcontracted to oversee the quality and structural design compliance of the entire cast in place concrete and curtain wall embed system on the project. In a partnership with Harmon Glass and Atlantic Waterproofing, the glass and brick façade system will undergo stringent water tests to ensure the compliance of all waterproofing details and design facets.

BLOCKING AND STACKING

One very unique owner requirement did not surface until later in the project timeline, after initial coordination efforts had reached near-completion levels. Preliminary coordination efforts between the owner and the future tenant did not effectively address the tenant's office logistics needs. Upon further investigation, the owner discovered that the tenants had spacial requirements that were drastically different from the preliminary assumptions. The realignment of these core areas, known as Blocking and Stacking because of the office logistic related purpose of the changes, led to many alterations of the original design. Open office areas, conference rooms and private offices required modifications to their size and locations within the building. Unfortunately, after an architectural design has gone through the structural, mechanical and electrical design process, it is very difficult to change the location and sizes of these areas. Re-coordination of the systems that support these spaces lengthened the design and coordination processes by approximately four months, and required countless in-field adjustments to system components that had already been installed. Main ducts, VAV boxes and cable trays required drastic alterations to meet the aspects of the new design. This not only required the removal of the existing system layouts, but also prompted the painstaking process of concrete core drilling to provide the proper floor penetrations and system hanger locations to allow for the repositioning of these systems. On the lowest level of Building One alone, these changes amounted to contract change orders in excess of $2.5M. These costs will unavoidably be reflected on every subsequent floor in each of the three buildings as the Blocking and Stacking process continues to take form.

PROJECT TEAM REQUIREMENTS

Stringent project controls and a watchful field staff are crucial in the effort to meet the aforementioned owner requirements and expectations. The quality control measures in place help establish a system of controls that will ensure that the installed systems and materials are of the highest craftsmanship and meet or exceed the project specifications and requirements. The presence of an experienced and attentive field staff will further support these quality control measures, assuring that the work in place is of high quality and meets the design standards. The support provided by the on-site design team members promotes a continual awareness of the design intent and minimizes the application of in-field coordination techniques that conflict with the project specifications. This attribute of the design-build team alone is irreplaceable, as it helps guarantee that actions taken in the field are not later deemed unacceptable, requiring additional remediation that can adversely affect the project schedule and budget.

PROJECT DELIVERY SYSTEM

* **See Appendix D for Organizational Chart**

As previously discussed, the design-build project delivery method is utilized on this project. The main driving force behind this decision is the owner and tenant's desire to implement a fast-track approach in order to expedite the construction process. Additionally, the complex bridging documents produced by Perkins & Will, along with the requirements associated with a LEED Gold rating demanded an interdisciplinary team that can effectively work together in order to understand and foresee the relationships between the design and construction of advanced building systems and sustainable features, ensuring a cohesive design that is not only highly efficient and functional, but also constructible.

CONTRACT TYPES

The relationship connections in the organizational chart found in Appendix D are numbered based upon the type of contract between the two connected parties. Below is an explanation of these contractual agreements.

#1 – Owner/Perkins & Will Contract – Guaranteed Maximum Price
The owner of the project partnered with Perkins & Will to created bridging documents that would later become the basis of design for the Clark design-build team. Perkins & Will was awarded a guaranteed maximum price contract that held them responsible for the production of initial bridging documents on the project. Their contract was completed when the design was turned over to the Clark design-build team for further development.

#2 – Owner/Clark Construction Contract – Lump Sum
Clark Construction and its design partners were awarded a lump sum bid contract that includes all design and construction costs. Due to the foresight of various unforeseen conditions and possibility of owner change orders, a negotiation clause was added to the lump sum contract to allow Clark Construction to add appropriate additions to the contract in the event of a change directive.

#3 – Clark Construction/Design Partners Contract – Negotiated GMP
The designer partners on this project were subcontracted by Clark Construction through negotiated guaranteed-maximum-price contracts. The designers submitted bids that included design costs and fees associated with the initial design process, but were able to negotiate reimbursements for any changes that led to further design work in the future.

#4 & #5 – Design-Build Team/Engineers Contracts – Negotiated GMP
Similar to the contracts utilized between Clark Construction and its design partners, the design-build team entered into negotiated guaranteed-maximum-price contracts with engineers and consultants. These contracts included costs and fees for the design and consulting work during the originally planned design period, but included a negotiation clause through which the firms could gain reimbursements for any additional work associated with project change orders and unforeseen conditions.

#6 – Clark Construction/Subcontractor Contracts – Negotiated GMP
In order to preserve the competitive bidding process, Clark Construction solicited guaranteed maximum price bids from interested contractors. Like the other GMP contracts, these too included a negotiation clause that permits subcontractors to seek proper payment for changing project specifications and conditions.

#7 – Subcontractor/Third-Tier Subcontractor Contracts – Not Available

It could be reasonably assumed that subcontractors and third-tier subcontractors were bound by negotiated guaranteed maximum price contracts as well. This would allow the subcontractors to evaluate their subcontractors on a level playing field, but also allow the third-tier subcontractors to negotiate the cost of any changes in the contract documents.

DESIGN-BUILD TEAM SELECTION

Clark Construction, in a partnership with WDG Architecture and McKissack and McKissack (the Architects of Record on this project), put together a response to the owner's RFP. In addition to selecting the team's architects early in the RFP response process, the proposal also included preferred engineering firms, who had been contacted when the RFP was released to local general contractors in order to provide accurate pricing and company capabilities that could be included in the proposal. This comprehensive approach to the project proposal process allowed Clark Construction to assemble a very competitive budget and schedule that incorporated the industry experience of many firms. The bid was awarded to the design-build team not only because of their competitive pricing, but also their ability to convince the owner that they could bring together the most competent and experienced team members to ensure the future success of the project.

BONDS AND INSURANCE

Clark Construction was required to provide a Performance & Payment (P&P) bond that could cover the total $535M project budget. This was not an issue due to Clark Construction's high bonding capacity. Clark also opted to offer a Contractor Provided Insurance Program to its subcontractors. Clark prefers that subcontractors with large contract amounts participate in the CCIP in order to increase their in-house control over insurance claims that may be incurred over the life of the project.

Since Clark is capable of bonding the entire $535M project, the owner themselves did not require P&P bonds from individual subcontractors, however, in an attempt to reduce their exposure, Clark Construction requires P&P bonds for companies with $100,000+ contracts (most of the contractors on this project)

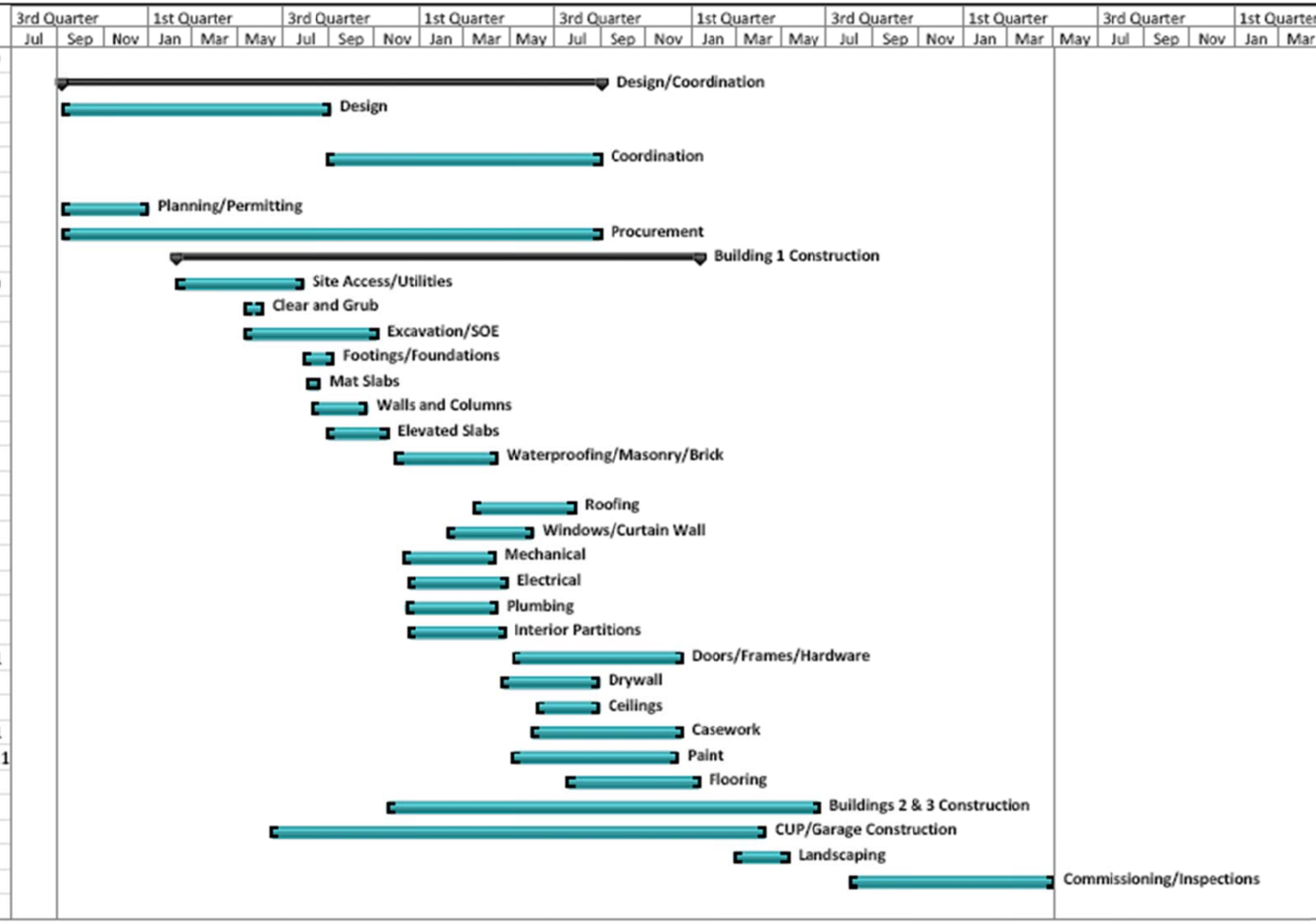
APPENDIX A – SUMMARY PROJECT SCHEDULE

2011 AE SENIOR THESIS

PATRICK LANINGER
CONSTRUCTION MANAGEMENT

SUMMARY PROJECT SCHEDULE - TECH ONE
SEPTEMBER 23, 2011

Task Name	Duration	Start	Finish
Notice to Proceed	0 days	Mon 8/31/09	Mon 8/31/09
Design/Coordination	**520 days**	**Mon 9/7/09**	**Fri 9/2/11**
Design	260 days	Mon 9/7/09	Fri 9/3/10
Preliminary Design Complete	0 days	Fri 9/3/10	Fri 9/3/10
Coordination	265 days	Mon 8/30/10	Fri 9/2/11
Preliminary Coordination Complete	0 days	Fri 9/2/11	Fri 9/2/11
Planning/Permitting	85 days	Mon 9/7/09	Fri 1/1/10
Procurement	520 days	Mon 9/7/09	Fri 9/2/11
Building 1 Construction	**504 days**	**Mon 2/8/10**	**Thu 1/12/12**
Site Access/Utilities	123 days	Mon 2/8/10	Wed 7/28/10
Clear and Grub	20 days	Mon 5/10/10	Fri 6/4/10
Excavation/SOE	130 days	Mon 5/10/10	Fri 11/5/10
Footings/Foundations	30 days	Wed 7/28/10	Tue 9/7/10
Mat Slabs	15 days	Mon 8/2/10	Fri 8/20/10
Walls and Columns	55 days	Mon 8/9/10	Fri 10/22/10
Elevated Slabs	60 days	Mon 8/30/10	Fri 11/19/10
Waterproofing/Masonry/Brick	100 days	Mon 11/29/10	Fri 4/15/11
Building 1 Watertight	0 days	Fri 4/15/11	Fri 4/15/11
Roofing	100 days	Mon 3/14/11	Fri 7/29/11
Windows/Curtain Wall	85 days	Mon 2/7/11	Fri 6/3/11
Mechanical	89 days	Thu 12/9/10	Tue 4/12/11
Electrical	97 days	Thu 12/16/10	Fri 4/29/11
Plumbing	90 days	Mon 12/13/10	Fri 4/15/11
Interior Partitions	93 days	Fri 12/17/10	Tue 4/26/11
Doors/Frames/Hardware	163 days	Fri 5/6/11	Tue 12/20/11
Drywall	94 days	Thu 4/21/11	Tue 8/30/11
Ceilings	60 days	Wed 6/8/11	Tue 8/30/11
Casework	146 days	Tue 5/31/11	Tue 12/20/11
Paint	160 days	Thu 5/5/11	Wed 12/14/11
Flooring	129 days	Mon 7/18/11	Thu 1/12/12
Buildings 2 & 3 Construction	417 days	Thu 11/18/10	Fri 6/22/12
CUP/Garage Construction	476 days	Tue 6/15/10	Tue 4/10/12
Landscaping	54 days	Tue 2/28/12	Fri 5/11/12
Commissioning/Inspections	198 days	Wed 8/1/12	Fri 5/3/13
Substantial Completion	0 days	Fri 5/3/13	Fri 5/3/13



Project: Summary Schedule
Date: Wed 9/21/11

Milestone ◆ Summary Manual Task

OFFICE BUILDING
NORTHEAST UNITED STATES

APPENDIX B – RSMEANS COSTWORKS REPORTS

Estimate Name: **Tech 1**	
Building Type:	**Office, 5-10 Story with Face Brick with Concrete Block Back-up / R/Conc. Frame**
Location:	[redacted]
Stories:	**5**
Story Height (L.F.):	**14**
Floor Area (S.F.):	**345000**
Labor Type:	**Union**
Basement Included:	**No**
Data Release:	**Year 2010 Quarter 1**
Cost Per Square Foot:	**$134.28**
Building Cost:	**$46,328,500**

Costs are derived from a building model with basic components. Scope differences and market conditions can cause costs to vary significantly.

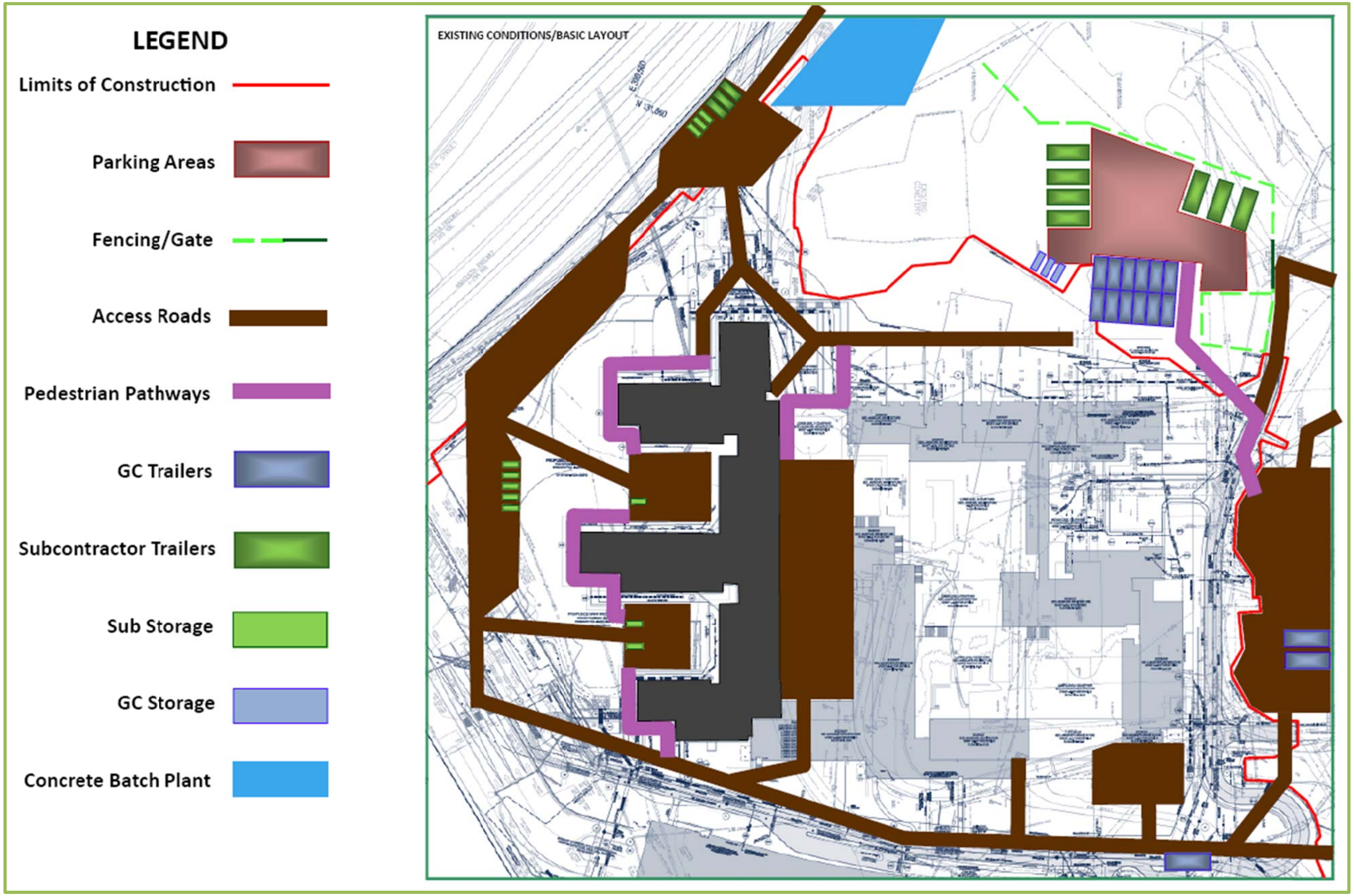
	% of Total	Cost Per S.F.	Cost
A Substructure	**3.2%**	**$3.79**	**$1,308,500**
A1010 Standard Foundations		**$2.02**	**$697,500**
Strip footing, concrete, reinforced, load 11.1 KLF, soil bearing capacity 6 KSF, 12" deep x 24" wide			
Spread footings, 3000 PSI concrete, load 800K, soil bearing capacity 6 KSF, 12' - 0" square x 37" deep			
A1030 Slab on Grade		**$0.96**	**$329,500**
Slab on grade, 4" thick, non industrial, reinforced			
A2010 Basement Excavation		**$0.06**	**$19,000**
Excavate and fill, 10,000 SF, 4' deep, sand gravel, or common earth, on site storage			
A2020 Basement Walls		**$0.76**	**$262,500**
Foundation wall, CIP, 4' wall height, direct chute, .148 CY/LF, 7.2 PLF, 12" thick			
B Shell	**30.5%**	**$36.39**	**$12,555,000**
B1010 Floor Construction		**$15.56**	**$5,366,500**
Cast-in-place concrete column, 20" square, tied, 800K load, 12' story height, 394 lbs/LF, 6000PSI			
Cast-in-place concrete column, 20" square, tied, 900K load, 12' story height, 394 lbs/LF, 6000PSI			
Cast-in-place concrete column, 20", square, tied, minimum reinforcing, 500K load, 10'-14' story height, 375 lbs/LF, 4000PSI			
Flat plate, concrete, 9" slab, 20" column, 20'x25' bay, 75 PSF superimposed load, 188 PSF total load			
B1020 Roof Construction		**$2.72**	**$940,000**
Floor, concrete, beam and slab, 20'x25' bay, 40 PSF superimposed load, 18" deep beam, 8.5" slab, 146 PSF total load			
B2010 Exterior Walls		**$12.63**	**$4,358,000**
Brick wall, composite double wythe, standard face/CMU back-up, 8" thick, perlite core fill			

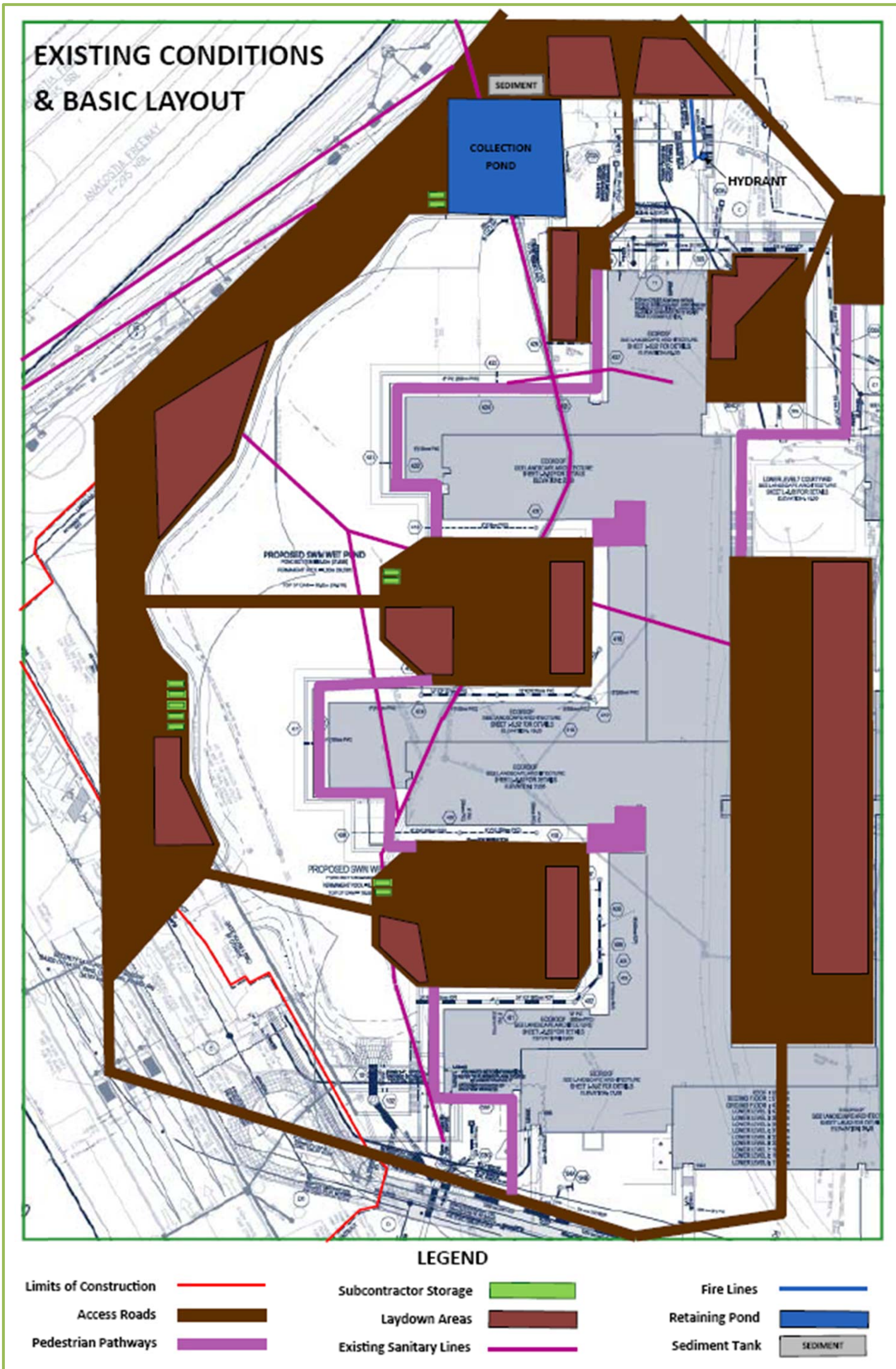
B2020 Exterior Windows			**$4.18**	**$1,443,000**
Windows, aluminum, sliding, insulated glass, 5' x 3'				
B2030 Exterior Doors			**$0.24**	**$82,000**
Door, aluminum & glass, with transom, narrow stile, double door, hardware, 6'-0" x 10'-0" opening				
Door, steel 18 gauge, hollow metal, 1 door with frame, no label, 3'-0" x 7'-0" opening				
B3010 Roof Coverings			**$1.06**	**$365,500**
Roofing, asphalt flood coat, gravel, base sheet, 3 plies 15# asphalt felt, mopped				
Insulation, rigid, roof deck, composite with 2" EPS, 1" perlite				
Roof edges, aluminum, duranodic, .050" thick, 6" face				
Flashing, aluminum, no backing sides, .019"				
C Interiors		**19.7%**	**$23.58**	**$8,136,500**
C1010 Partitions			**$2.88**	**$992,000**
Metal partition, 5/8" water resistant gypsum board face, no base layer, 3-5/8" @ 24" OC framing ,same opposite face, no insulation				
1/2" fire ratedgypsum board, taped & finished, painted on metal furring				
C1020 Interior Doors			**$2.53**	**$874,000**
Door, single leaf, kd steel frame, hollow metal, commercial quality, flush, 3'-0" x 7'-0" x 1-3/8"				
C1030 Fittings			**$0.69**	**$239,000**
Toilet partitions, cubicles, ceiling hung, plastic laminate				
C2010 Stair Construction			**$2.66**	**$916,500**
Stairs, steel, cement filled metal pan & picket rail, 16 risers, with landing				
C3010 Wall Finishes			**$0.87**	**$299,000**
Painting, interior on plaster and drywall, walls & ceilings, roller work, primer & 2 coats				
Vinyl wall covering, fabric back, medium weight				
C3020 Floor Finishes			**$7.88**	**$2,717,500**
Carpet, tufted, nylon, roll goods, 12' wide, 36 oz				
Carpet, padding, add to above, minimum				
Vinyl, composition tile, maximum				
Tile, ceramic natural clay				
C3030 Ceiling Finishes			**$6.08**	**$2,098,500**
Acoustic ceilings, 3/4"mineral fiber, 12" x 12" tile, concealed 2" bar & channel grid, suspended support				
D Services		**46.6%**	**$55.74**	**$19,232,000**
D1010 Elevators and Lifts			**$15.37**	**$5,303,500**
Traction, geared passenger, 3500 lb, 8 floors, 12' story height, 2 car group, 200 FPM				
D2010 Plumbing Fixtures			**$2.27**	**$781,500**
Water closet, vitreous china, bowl only with flush valve, wall hung				
Urinal, vitreous china, wall hung				
Lavatory w/trim, vanity top, PE on CI, 20" x 18"				
Service sink w/trim, PE on CI,wall hung w/rim guard, 24" x 20"				
Water cooler, electric, wall hung, 8.2 GPH				
Water cooler, electric, wall hung, wheelchair type, 7.5 GPH				
D2020 Domestic Water Distribution			**$0.50**	**$174,000**
Gas fired water heater, commercial, 100< F rise, 200 MBH input, 192 GPH				

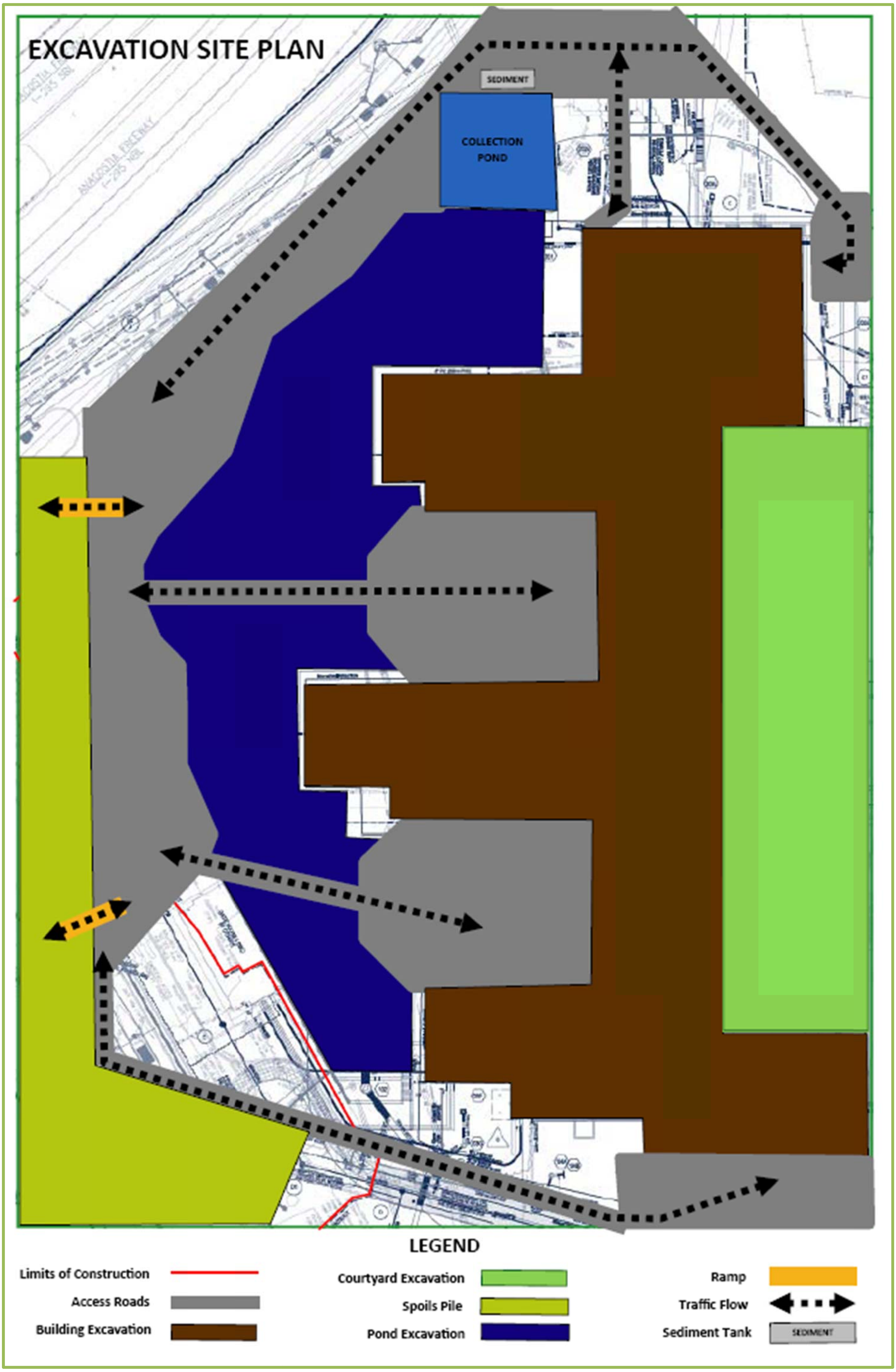
D2040	**Rain Water Drainage**		**$0.26**	**$88,000**
	Roof drain, CI, soil,single hub, 5" diam, 10' high			
	Roof drain, CI, soil,single hub, 5" diam, for each additional foot add			
D3050	**Terminal & Package Units**		**$15.92**	**$5,491,000**
	Rooftop, multizone, air conditioner, offices, 25,000 SF, 79.16 ton			
D4010	**Sprinklers**		**$2.73**	**$943,500**
	Wet pipe sprinkler systems, steel, light hazard, 1 floor, 10,000 SF			
	Wet pipe sprinkler systems, steel, light hazard, each additional floor, 10,000 SF			
	Standard High Rise Accessory Package 8 story			
D4020	**Standpipes**		**$0.66**	**$229,000**
	Wet standpipe risers, class III, steel, black, sch 40, 4" diam pipe, 1 floor			
	Wet standpipe risers, class III, steel, black, sch 40, 4" diam pipe, additional floors			
	Fire pump, electric, with controller, 5" pump, 100 HP, 1000 GPM			
	Fire pump, electric, for jockey pump system, add			
D5010	**Electrical Service/Distribution**		**$0.45**	**$154,000**
	Service installation, includes breakers, metering, 20' conduit & wire, 3 phase, 4 wire, 120/208 V, 1600 A			
	Feeder installation 600 V, including RGS conduit and XHHW wire, 60 A			
	Feeder installation 600 V, including RGS conduit and XHHW wire, 200 A			
	Feeder installation 600 V, including RGS conduit and XHHW wire, 1600 A			
	Switchgear installation, incl switchboard, panels & circuit breaker, 1600 A			
D5020	**Lighting and Branch Wiring**		**$11.28**	**$3,892,500**
	Receptacles incl plate, box, conduit, wire, 16.5 per 1000 SF, 2.0 W per SF, with transformer			
	Miscellaneous power, 1.2 watts			
	Central air conditioning power, 4 watts			
	Motor installation, three phase, 460 V, 15 HP motor size			
	Motor feeder systems, three phase, feed to 200 V 5 HP, 230 V 7.5 HP, 460 V 15 HP, 575 V 20 HP			
	Motor connections, three phase, 200/230/460/575 V, up to 5 HP			
	Motor connections, three phase, 200/230/460/575 V, up to 100 HP			
	Fluorescent fixtures recess mounted in ceiling, 1.6 watt per SF, 40 FC, 10 fixtures @32watt per 1000 SF			
D5030	**Communications and Security**		**$5.24**	**$1,807,500**
	Telephone wiring for offices & laboratories, 8 jacks/MSF			
	Communication and alarm systems, fire detection, addressable, 100 detectors, includes outlets, boxes, conduit and wire			
	Fire alarm command center, addressable with voice, excl. wire & conduit			
	Internet wiring, 8 data/voice outlets per 1000 S.F.			
D5090	**Other Electrical Systems**		**$1.07**	**$367,500**
	Generator sets, w/battery, charger, muffler and transfer switch, diesel engine with fuel tank, 100 kW			
	Uninterruptible power supply with standard battery pack, 15 kVA/12.75 kW			
E	**Equipment & Furnishings**	**0.0%**	**$0.00**	**$0**
E1090	**Other Equipment**		**$0.00**	**$0**
F	**Special Construction**	**0.0%**	**$0.00**	**$0**
G	**Building Sitework**	**0.0%**	**$0.00**	**$0**

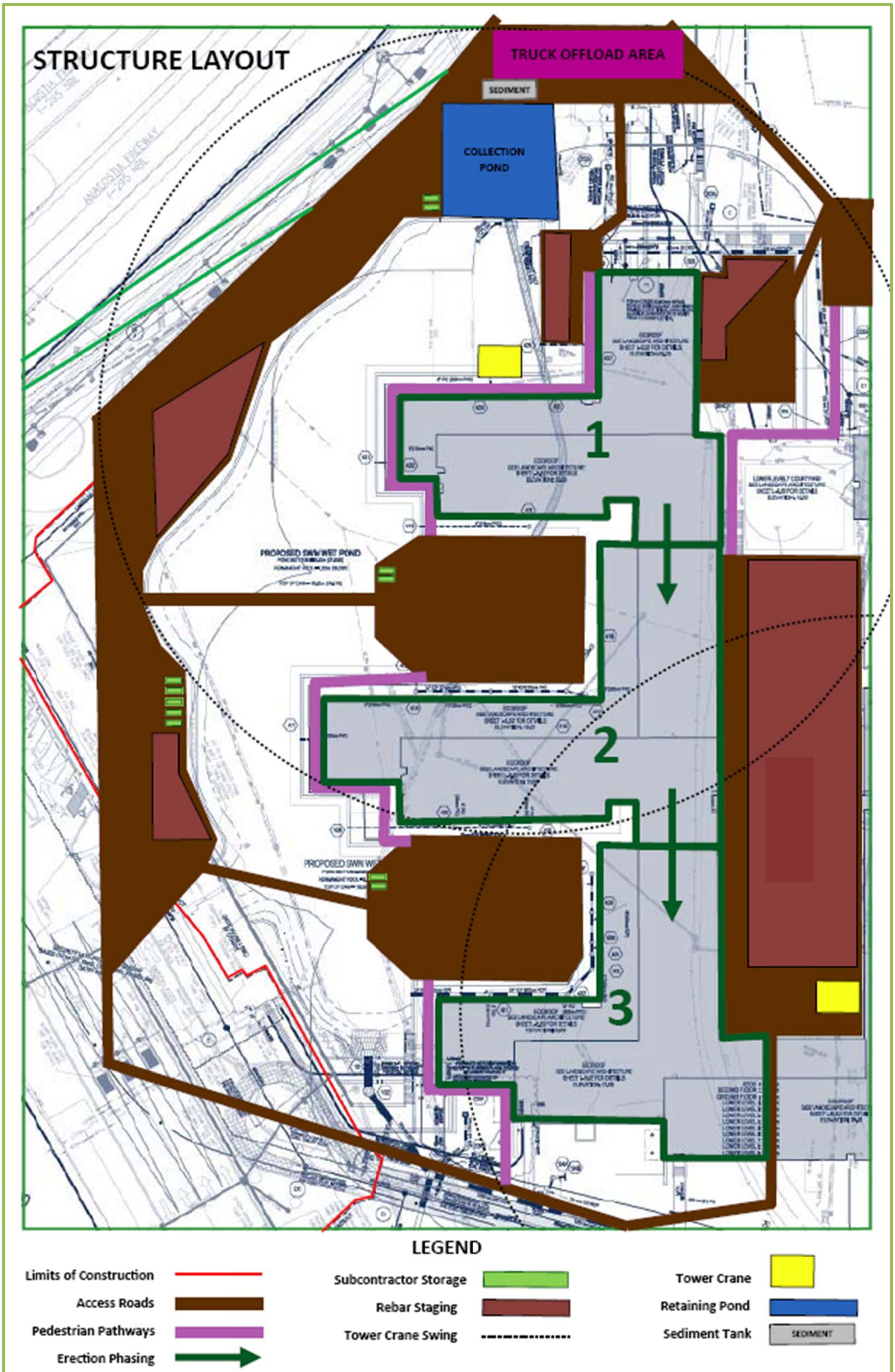
SubTotal	**100%**	**$119.51**	**$41,232,000**
Contractor Fees (GC,Overhead,Profit)	**6.0%**	**$7.17**	**$2,474,000**
Architectural Fees	**6.0%**	**$7.60**	**$2,622,500**
User Fees	**0.0%**	**$0.00**	**$0**
Total Building Cost		**$134.28**	**$46,328,500**

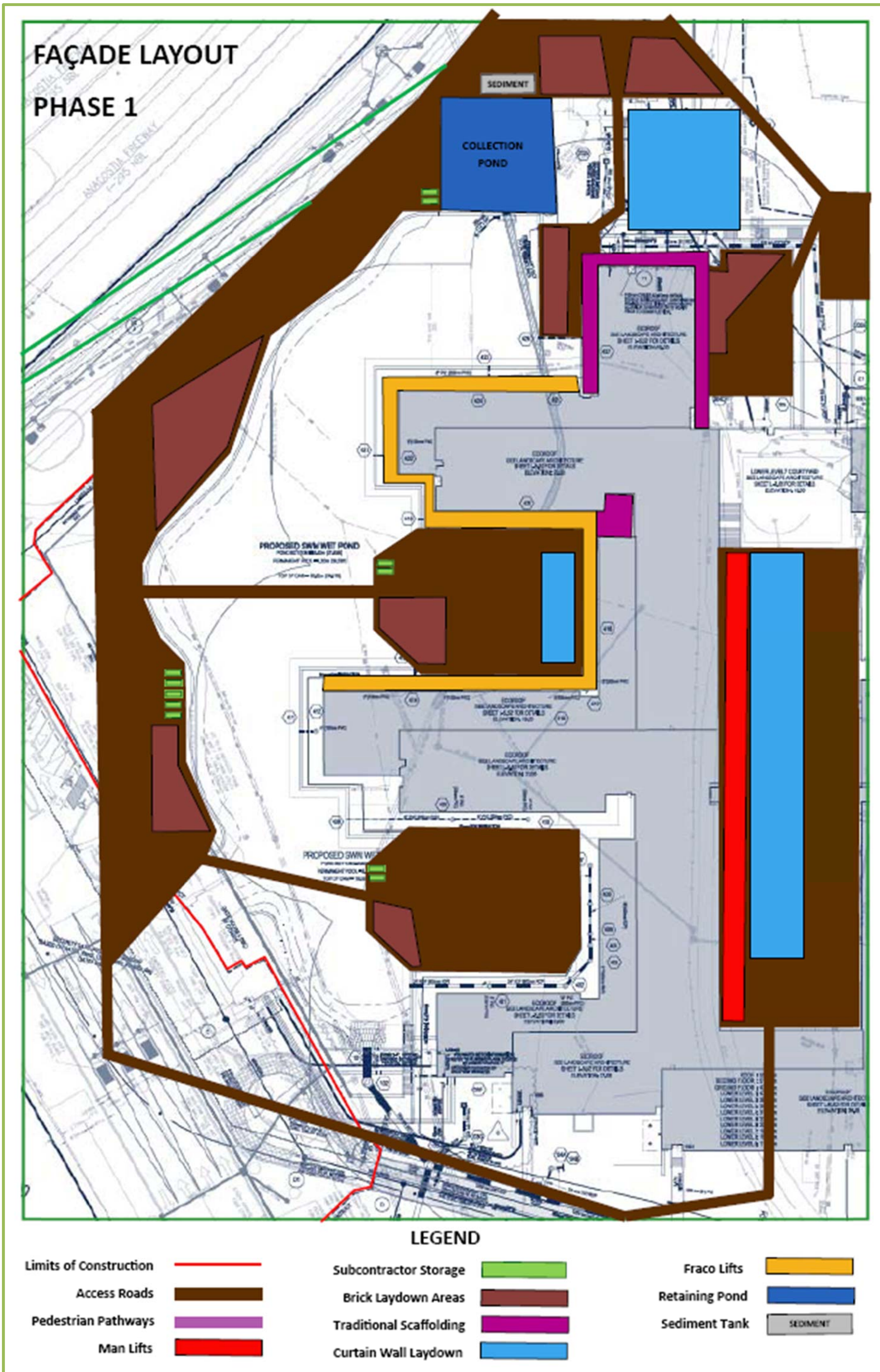
APPENDIX C – SITE PLANS

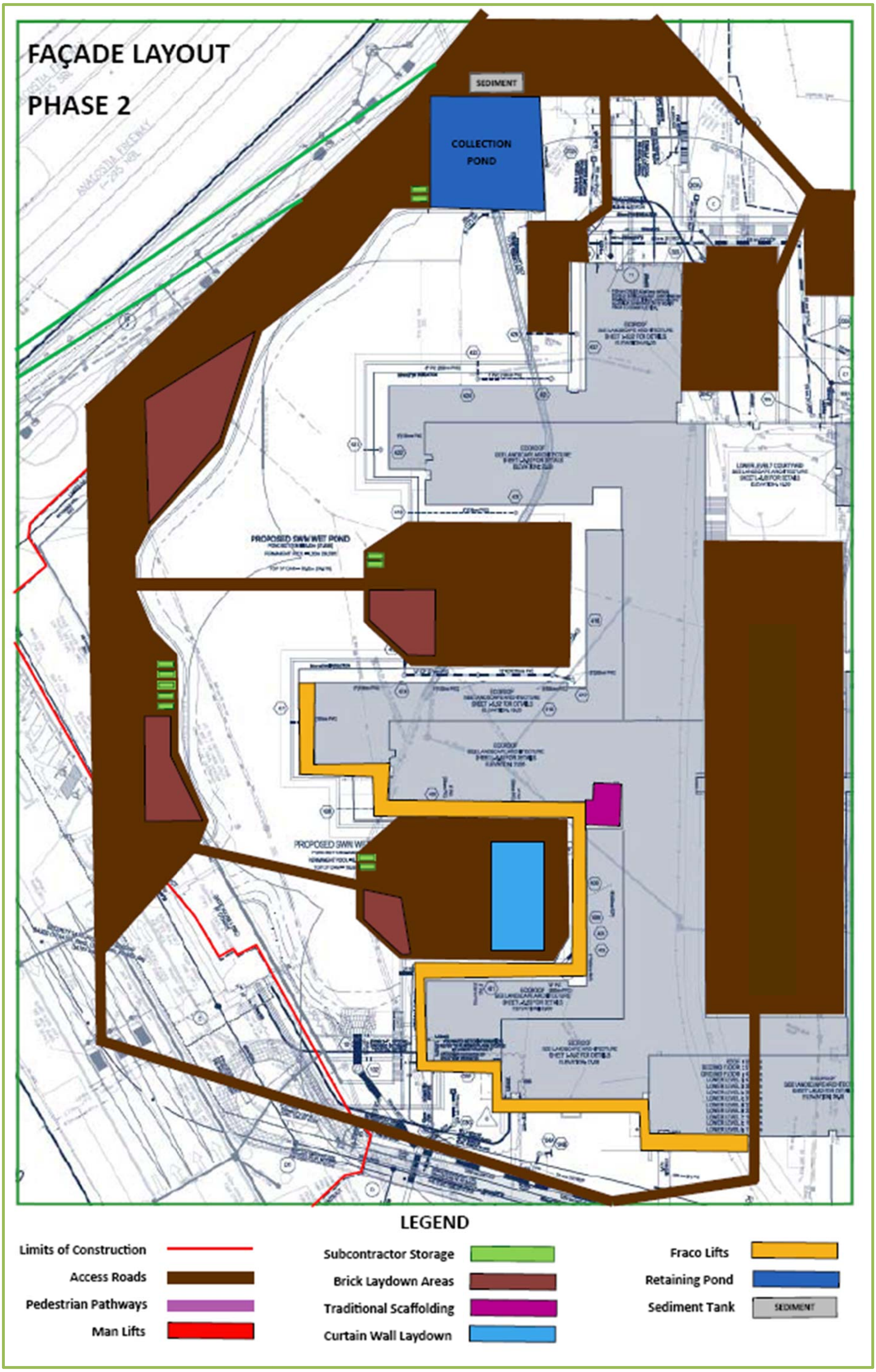

LEGEND
Limits of Construction
Parking Areas
Fencing/Gate
Access Roads
Pedestrian Pathways
GC Trailers
Subcontractor Trailers
Sub Storage
GC Storage
Concrete Batch Plant
EXISTING CONDITIONS/BASIC LAYOUT


EXISTING CONDITIONS
& BASIC LAYOUT
SEDIMENT
COLLECTION POND
HYDRANT
PROPOSED SWM WET POND
LEGEND
Limits of Construction
Access Roads
Pedestrian Pathways
Subcontractor Storage
Laydown Areas
Existing Sanitary Lines
Fire Lines
Retaining Pond
Sediment Tank
SEDIMENT

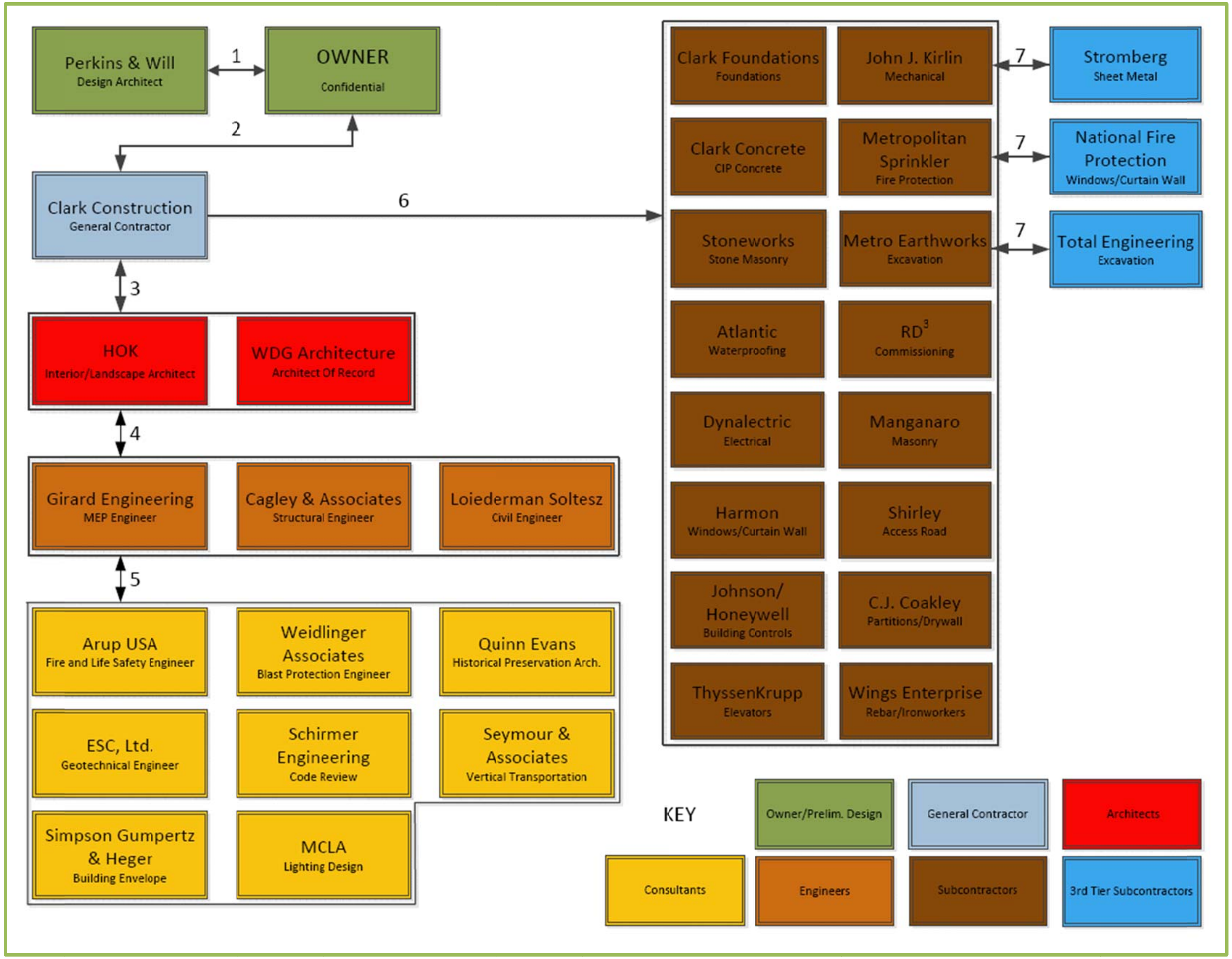

EXCAVATION SITE PLAN
SEDIMENT
COLLECTION POND
LEGEND
Limits of Construction
Access Roads
Building Excavation
Courtyard Excavation
Spoils Pile
Pond Excavation
Ramp
Traffic Flow
Sediment Tank
SEDIMENT


STRUCTURE LAYOUT
TRUCK OFFLOAD AREA
SEDIMENT
COLLECTION POND
1
2
3
PROPOSED SWM WET POND
LEGEND
Limits of Construction
Access Roads
Pedestrian Pathways
Erection Phasing
Subcontractor Storage
Rebar Staging
Tower Crane Swing
Tower Crane
Retaining Pond
Sediment Tank
SEDIMENT


FAÇADE LAYOUT
PHASE 1
SEDIMENT
COLLECTION POND
PROPOSED SWM WET POND
LEGEND
Limits of Construction
Access Roads
Pedestrian Pathways
Man Lifts
Subcontractor Storage
Brick Laydown Areas
Traditional Scaffolding
Curtain Wall Laydown
Fraco Lifts
Retaining Pond
Sediment Tank
SEDIMENT


FAÇADE LAYOUT
PHASE 2
SEDIMENT
COLLECTION POND
LEGEND
Limits of Construction
Access Roads
Pedestrian Pathways
Man Lifts
Subcontractor Storage
Brick Laydown Areas
Traditional Scaffolding
Curtain Wall Laydown
Fraco Lifts
Retaining Pond
Sediment Tank

APPENDIX D – ORGANIZATIONAL CHART


Perkins & Will
Design Architect
1
OWNER
Confidential
2
Clark Construction
General Contractor
6
3
HOK
Interior/Landscape Architect
WDG Architecture
Architect Of Record
4
Girard Engineering
MEP Engineer
Cagley & Associates
Structural Engineer
Loiederman Soltesz
Civil Engineer
5
Arup USA
Fire and Life Safety Engineer
Weidlinger Associates
Blast Protection Engineer
Quinn Evans
Historical Preservation Arch.
ESC, Ltd.
Geotechnical Engineer
Schirmer Engineering
Code Review
Seymour & Associates
Vertical Transportation
Simpson Gumpertz & Heger
Building Envelope
MCLA
Lighting Design
Clark Foundations
Foundations
John J. Kirlin
Mechanical
Clark Concrete
CIP Concrete
Metropolitan Sprinkler
Fire Protection
Stoneworks
Stone Masonry
Metro Earthworks
Excavation
Atlantic
Waterproofing
RD3
Commissioning
Dynalectric
Electrical
Manganaro
Masonry
Harmon
Windows/Curtain Wall
Shirley
Access Road
Johnson/ Honeywell
Building Controls
C.J. Coakley
Partitions/Drywall
ThyssenKrupp
Elevators
Wings Enterprise
Rebar/Ironworkers
7
Stromberg
Sheet Metal
7
National Fire Protection
Windows/Curtain Wall
7
Total Engineering
Excavation
KEY
Owner/Prelim. Design
General Contractor
Architects
Consultants
Engineers
Subcontractors
3rd Tier Subcontractors